# Chlorophyll *a* and Phycocyanin from Hyperspectral Airborne and Hand-held Sensors on Lake Erie

[1]Andrea Vander Woude, [1]Dack Stuart, [2]Steve Ruberg, [1]Thomas Johengen, [3]Brandi McCarty, [3]Jim Churnside, [1]Danna Palladino, [1]Ashley Burtner
[1]University of Michigan Cooperative Institute of Limnology and Ecosystems Research,
[2]NOAA Great Lakes Environmental Research Laboratory, [3]NOAA Earth System Research Laboratory

**Research Question:** Are chlorophyll *a* and phycocyanin in blue-green algae detectable from hyperspectral sensors?
**Why?:** To warn water intake managers in the Western basin of Lake Erie when any bloom is present near their intake

## Integrative HAB Approach

Water Intake Locations

## Airborne Resonon Pika II


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| Spectral Range | 400-900 nm |
| Spatial Resolution | 2.1 m (depending on altitude) |
| Number of channels | 240 |
| Field of View | 16° |

## Satlantic Hypergun Hand-held Sensor

Hyperspectral ocean color sensor that measures water-leaving spectral radiance and sky downwelling irradiance.

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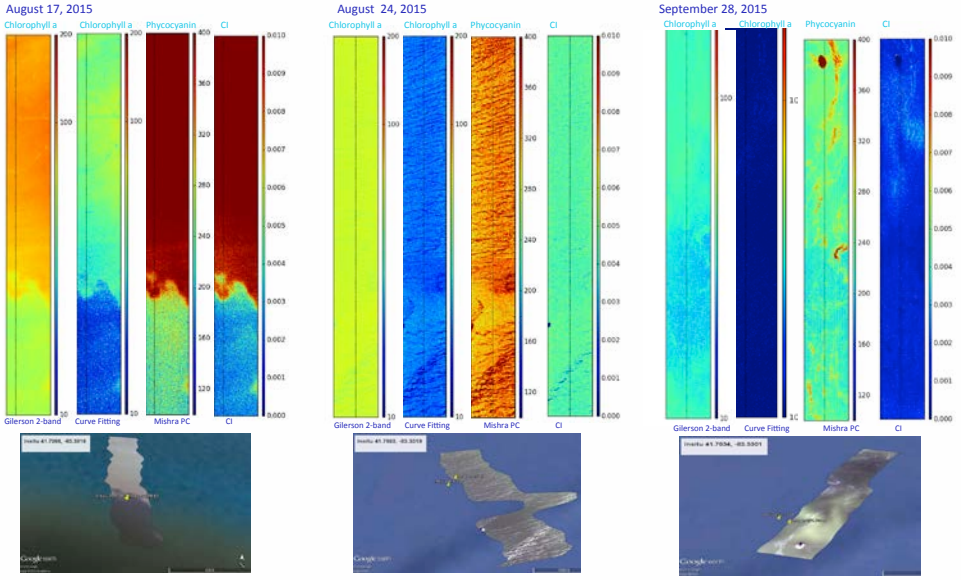
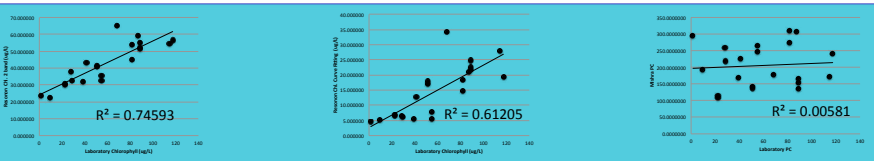
## Airborne Resonon Pika II Sensor - Results




### Algorithms




**Gilerson 2-band Chlorophyll (µg/L)**
Chl = 61.324*$R_{rs}(708)/R_{rs}(665)$ – 37.94

**Moore Curve Fitting Chlorophyll (µg/L)**
X = $R_{rs}(681)^2/(R_{rs}(664) * R_{rs}(709))$
Chl = $10^{-1.1280*\log10(X)^2-2.7796*\log10(X)+1.0422}$

**Mishra Phycocyanin (PC - µg/L)**
Ψ=$R_{rs}(560)/R_{rs}(665)$
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- *L*(550) < 4000 uflick
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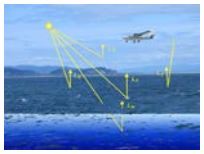

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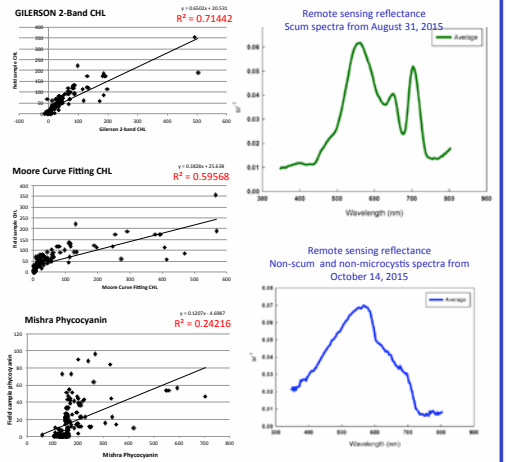


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- 4 different phytoplankton groups.
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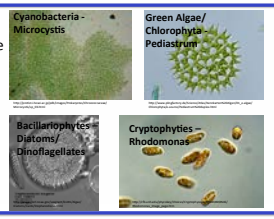


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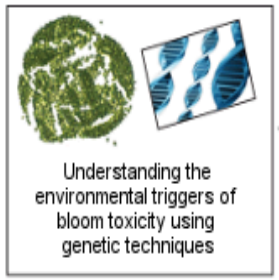
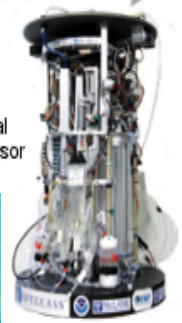


Understanding the environmental triggers of bloom toxicity using genetic techniques

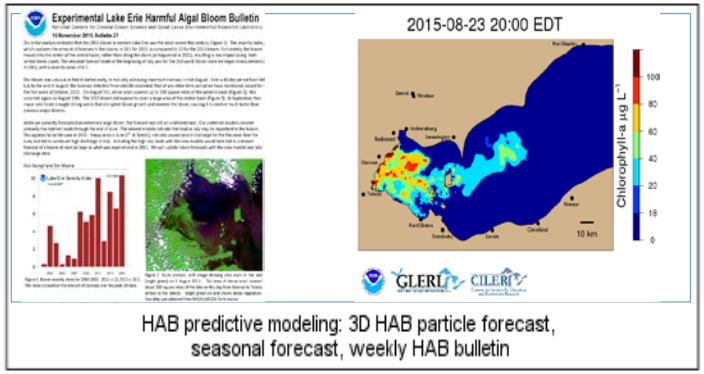
Monitoring and observations identify environmental conditions promoting *Microcystis* bloom occurrence and toxicity

Satellite algorithm assessment and remote sensing

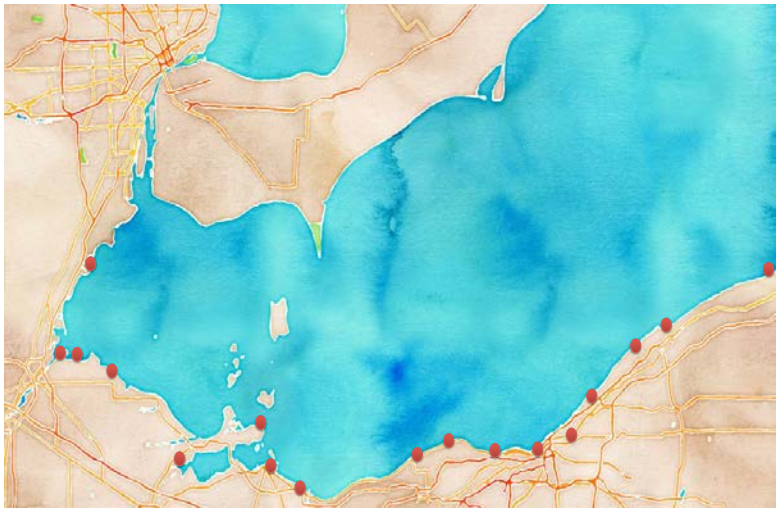
Zebra mussel and microcystin relationship



Environmental sample processor (ESP)




HAB predictive modeling: 3D HAB particle forecast, seasonal forecast, weekly HAB bulletin



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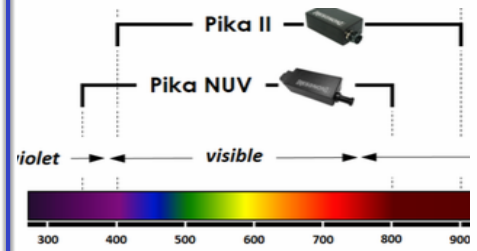




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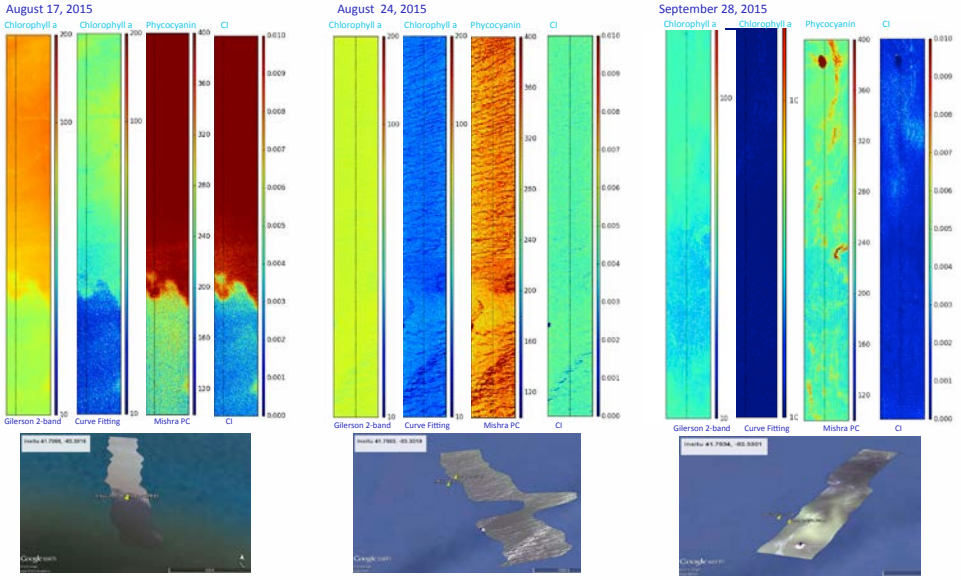


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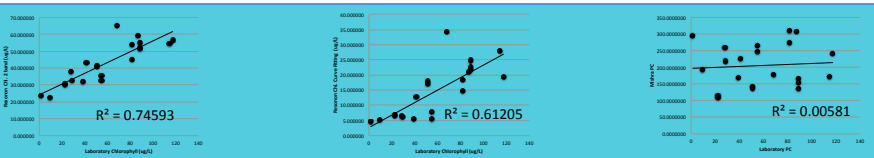


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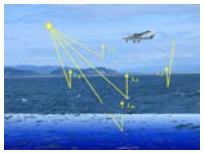

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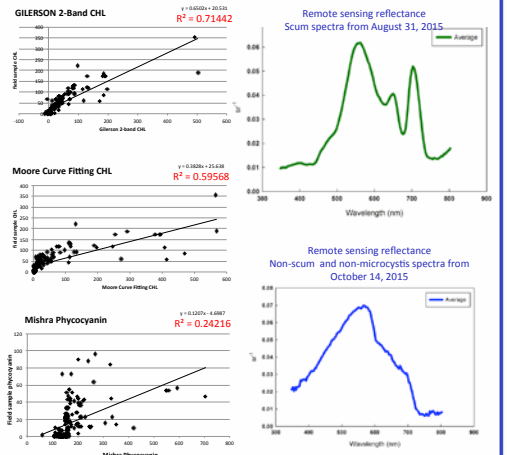


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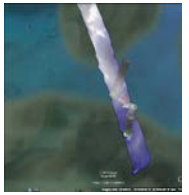

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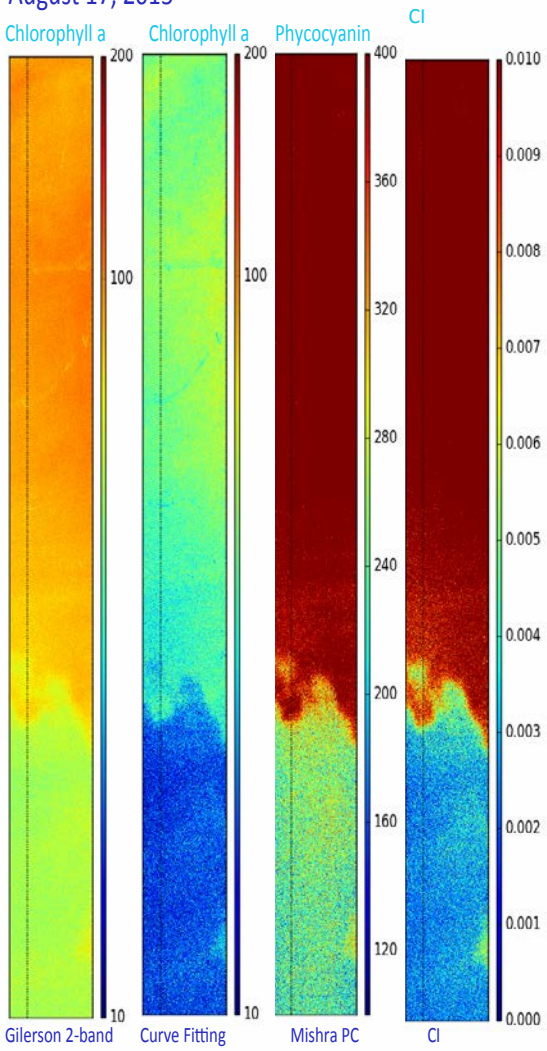


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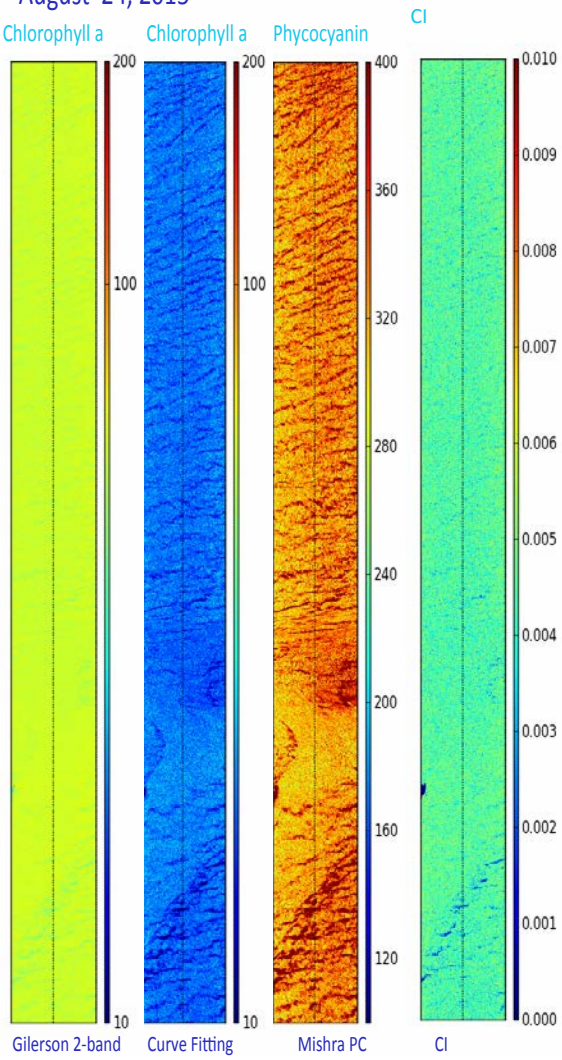


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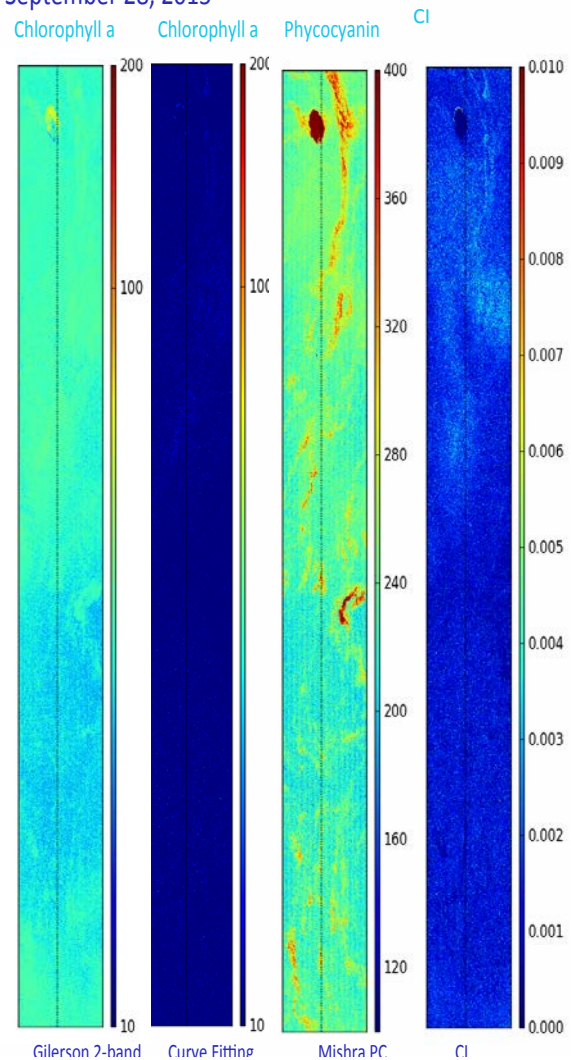




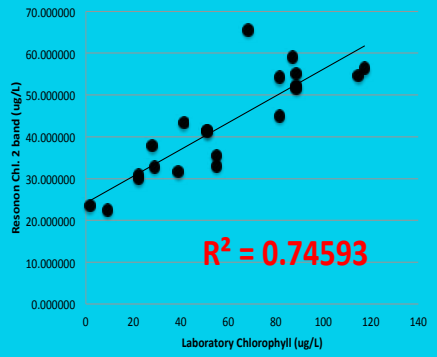


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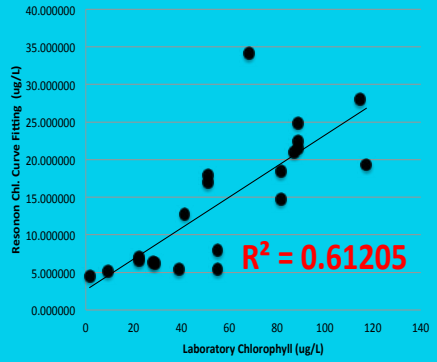


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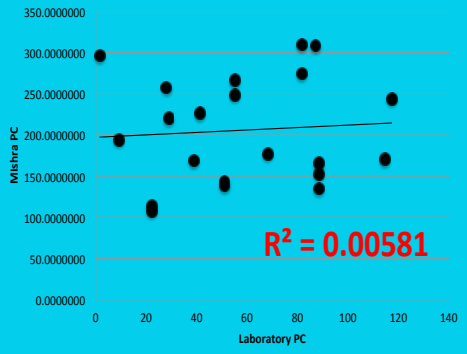


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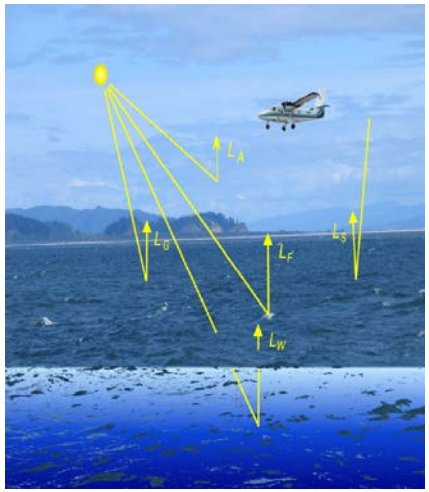


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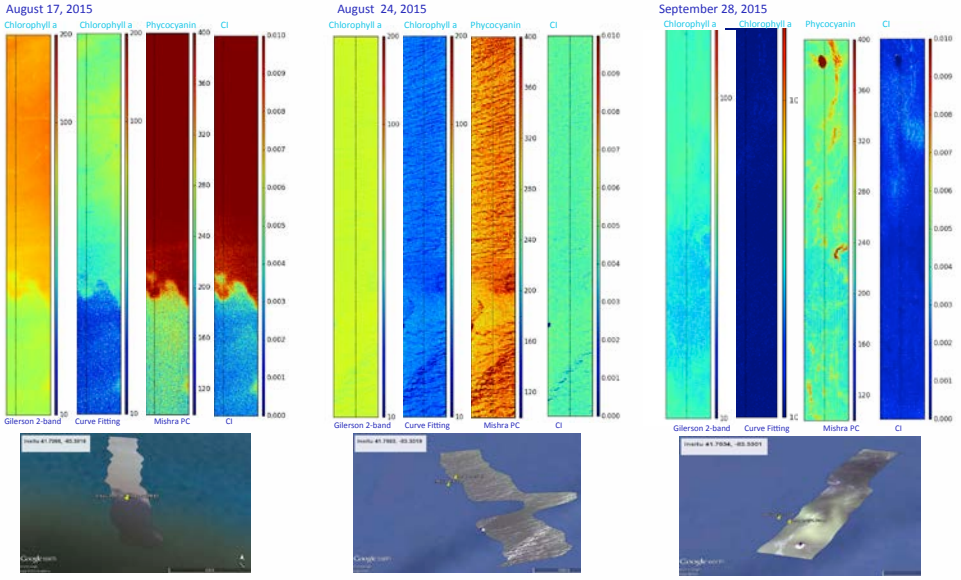


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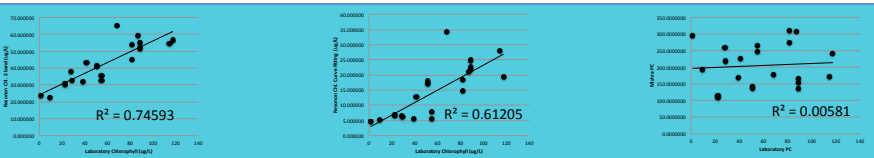


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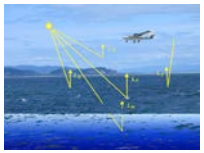

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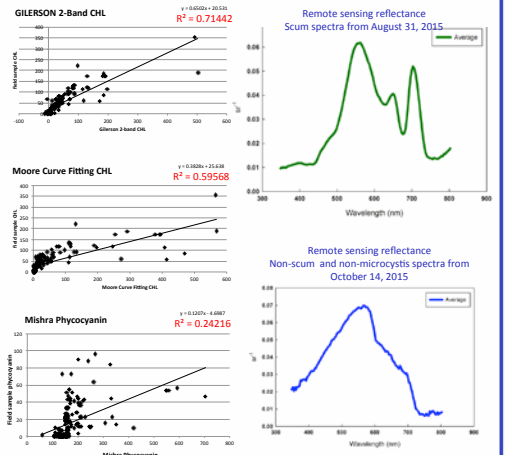


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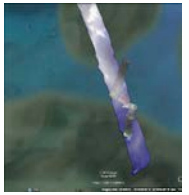

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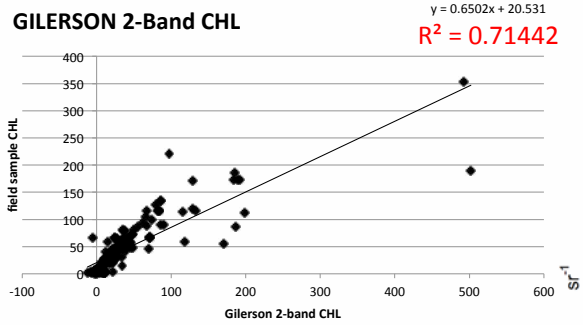
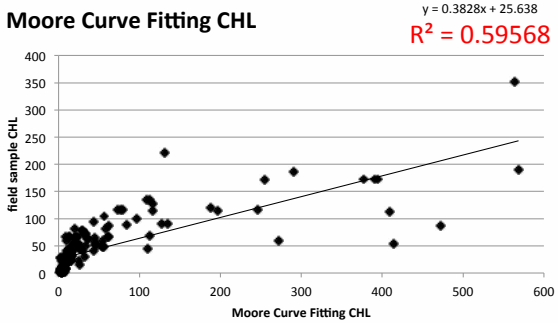
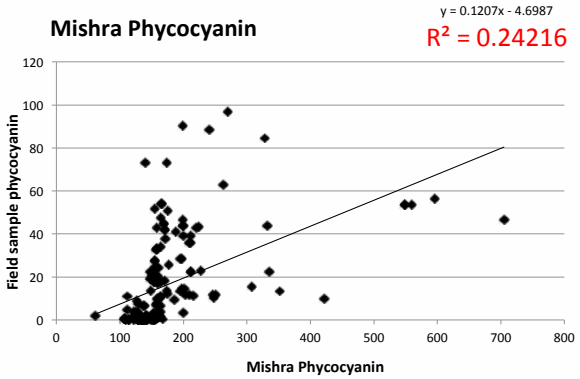
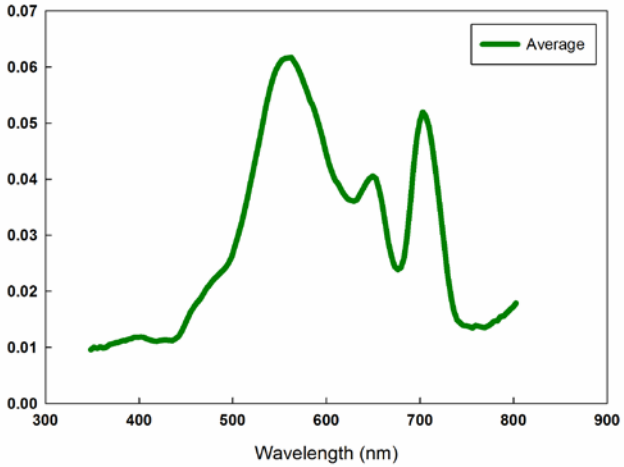


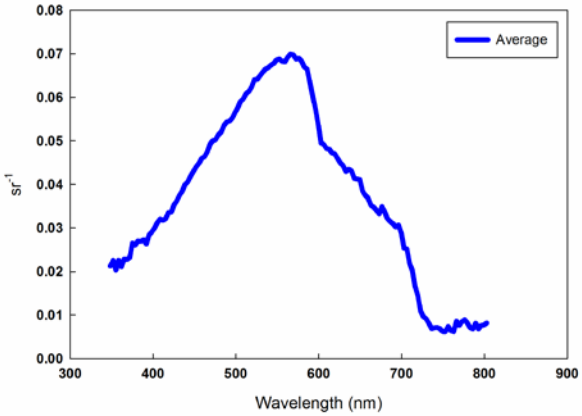




Remote sensing reflectance
Scum spectra from August 31, 2015




Remote sensing reflectance
Non-scum and non-microcystis spectra from October 14, 2015



# Chlorophyll *a* and Phycocyanin from Hyperspectral Airborne and Hand-held Sensors on Lake Erie

[1]Andrea Vander Woude, [1]Dack Stuart, [2]Steve Ruberg, [1]Thomas Johengen, [3]Brandi McCarty, [3]Jim Churnside, [1]Danna Palladino, [1]Ashley Burtner

[1]University of Michigan Cooperative Institute of Limnology and Ecosystems Research, [2]NOAA Great Lakes Environmental Research Laboratory, [3]NOAA Earth System Research Laboratory

**Research Question:** Are chlorophyll *a* and phycocyanin in blue-green algae detectable from hyperspectral sensors?
**Why?:** To warn water intake managers in the Western basin of Lake Erie when any bloom is present near their intake.

## Integrative HAB Approach

Water Intake Locations

## Airborne Resonon Pika II

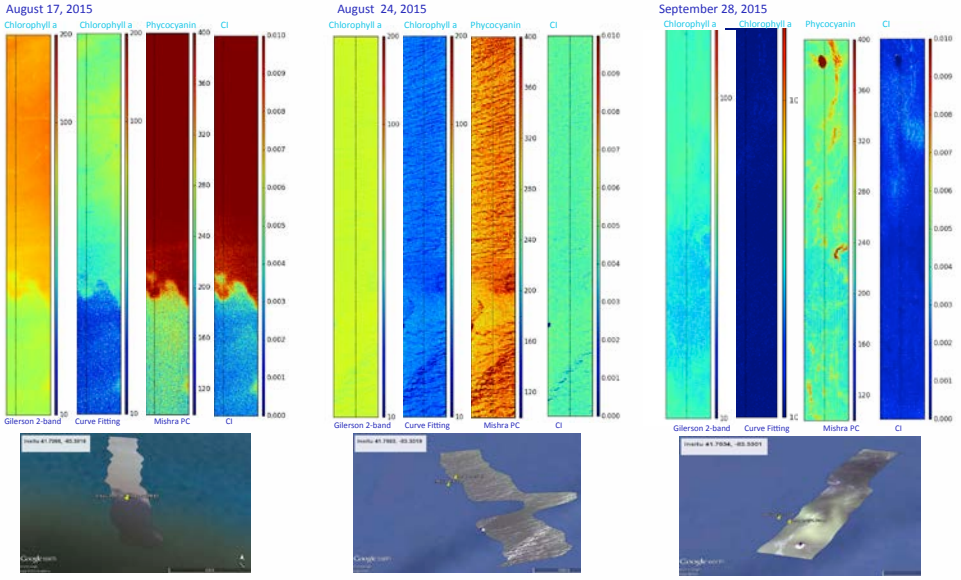

| | |
|---|---|
| Spectral Range | 400-900 nm |
| Spatial Resolution | 2.1 m (depending on altitude) |
| Number of channels | 240 |
| Field of View | 16° |

## Satlantic Hypergun Hand-held Sensor

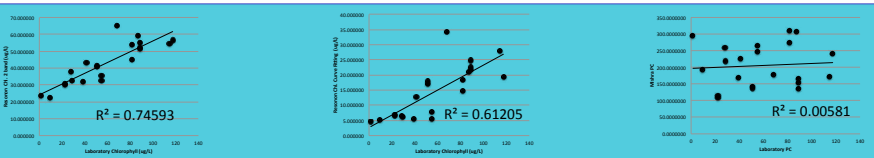
Hyperspectral ocean color sensor that measures water-leaving spectral radiance and sky downwelling irradiance.

| | |
|---|---|
| Spectral Range | 400-800 nm |
| Spectral Resolution | 3 nm |
| Number of channels | 137 |
| Field of view | 3° |

## Airborne Resonon Pika II Sensor - Results




## Algorithms



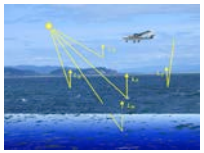

**Gilerson 2-band Chlorophyll (µg/L)**
Chl = 61.324*$R_{rs}(708)/R_{rs}(665)$ – 37.94

**Moore Curve Fitting Chlorophyll (µg/L)**
X = $R_{rs}(681)^2/(R_{rs}(664) * R_{rs}(709))$
Chl = $10^{-1.1280*\log10(X)^2-2.7796*\log10(X)+1.0422}$

**Mishra Phycocyanin (PC - µg/L)**
Ψ=$R_{rs}(560)/R_{rs}(665)$
PC3=$(R_{rs}(620)^{-1}-Ψ*R_{rs}(665)^{-1})*R_{rs}(778)$
PC = 480.92*$PC_3$+123.23

## Cloud detection & MODTRAN Atmospheric Correction (NOAA ESRL)

- *L*(550) < 4000 uflick
- Morphological opening with 5x5 pixel kernel.



- MODTRAN CLEAR SKY
- τ(550) = 0.2
- $L_{aerosol}$ calculated using black surface (looking down from aircraft)
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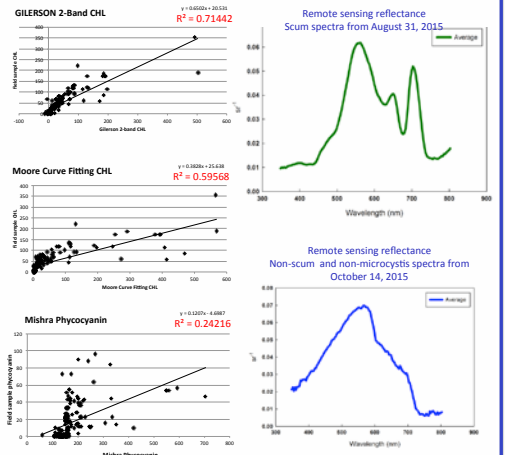
$$Rrs = \frac{L_{measured} - L_{aerosol} - L_{sky}}{E}$$

## Hand-held Satlantic Hypergun Sensor - Results




## Future Work

- Functional group maps of Lake Erie with a combination of absorption and backscatter spectra
- 4 different phytoplankton groups.
- End product will be maps of functional groups for each over flight.





## NASA Coincident Flyovers & Intercalibration

2015 coincident flyovers over Lake Erie and inter-calibration of sensors

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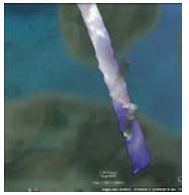

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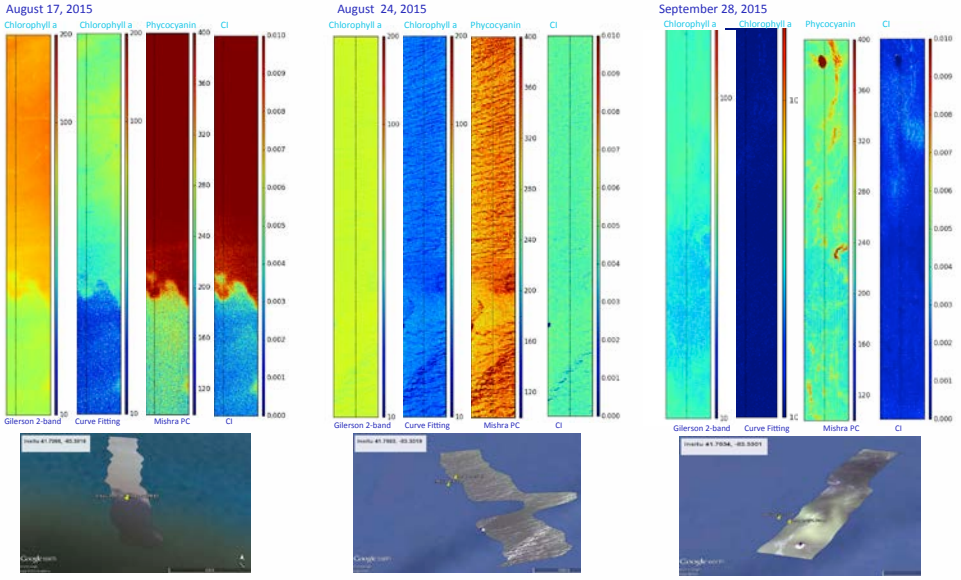


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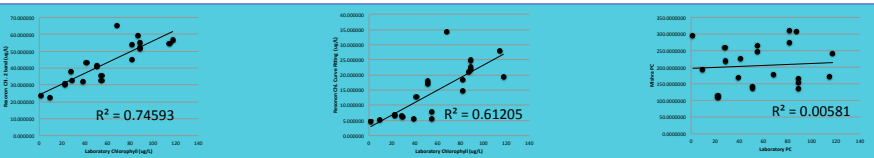


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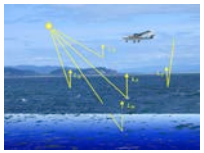

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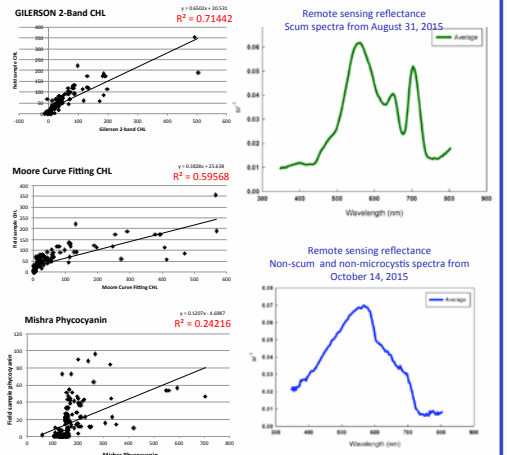


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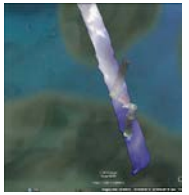

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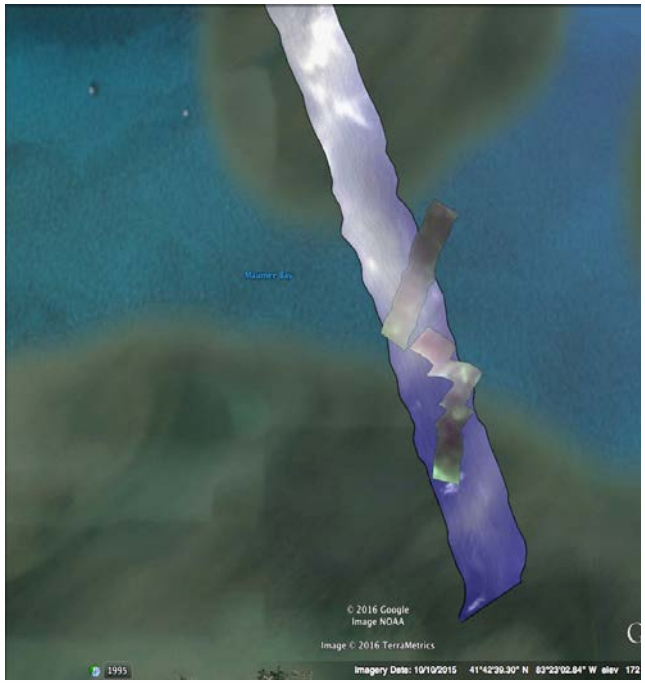

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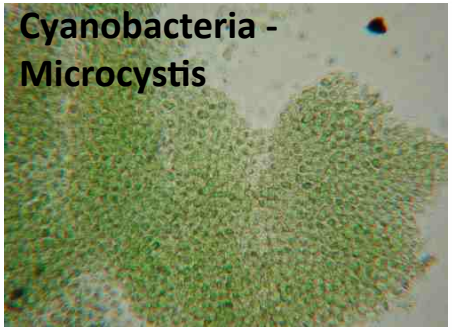
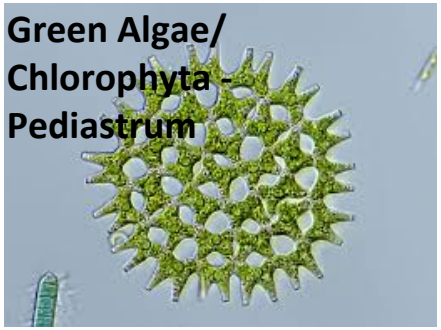
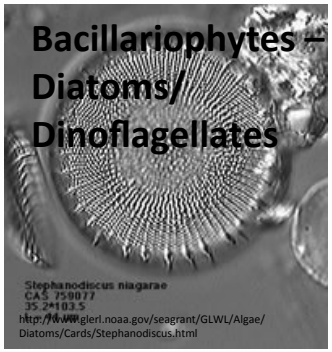


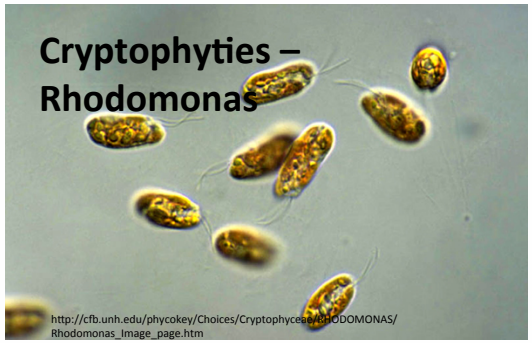

http://protist.i.hosei.ac.jp/pdb/images/Prokaryotes/Chroococcaceae/Microcystis/sp_03.html




http://www.plingfactory.de/Science/Atlas/Kennkarten%20Algen/01_e-algae/Chlorophyta/e-source/Pediastrum%20duplex.html




http://www.glerl.noaa.gov/seagrant/GLWL/Algae/Diatoms/Cards/Stephanodiscus.html




http://cfb.unh.edu/phycokey/Choices/Cryptophyceae/RHODOMONAS/Rhodomonas_Image_page.htm

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# Questions?